somewhat flexed from the level until it runs out on the southern edge of the basin. At the summit of the second dip another slope has been opened, and between these two slopes stands the giant coal-breaker, supplied with coal by the action of immense engines which draw, by means of wire rope, the loaded cars to its lofty height. The coal is drawn, in the second slope, up an incline of 424 feet by means of a wire rope 4300 feet in length, and nearly two inches in diameter. About 600 cars are daily hoisted by this rope, and the cars are drawn 174 feet up the incline within the breaker alone. This anticlinal, flexure, or saddle, brings into near proximity to the breaker a vertical mass of coal twelve feet in thickness and nearly 200 feet in height, and extending eastward and westward up and down the valley, to thin out as the conglomerate rises, basin-like, to its outcropping edge.

During 1880 there were three breakers in the basin, employing 389 men inside and 215 outside the mines. To open the mine and break up the coal from its beds 1514 kegs of powder, weighing twenty-five pounds each, were used, and the product of 330,444 tons of coal of 2240 lbs. each were sent to market. This valley and its plant for mining is the property of one family, and has proved, under their enterprise and energy, a princely domain.

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THE DEVELOPMENT OF THE MALE PROTHALLIUM OF THE FIELD HORSETAIL.

BY PROFESSOR DOUGLASS H. CAMPBELL.

AMONG the vascular cryptogams, perhaps none can be more satisfactorily studied than *Equisetum arvense*, both as regards the structure of the mature plant and that of the *prothallium*, the plant being a common one, and readily obtained for study. The growth of the fertile plant is very rapid, so that the cells are large and distinct, and being comparatively free from the silicious deposit so noticeable in most of the other species, it is much less difficult to examine. Finally, and what is of chief interest here, the spores germinate very readily if sown immediately after maturing, and offer a most interesting example, in their development, of the growth and division of cells. Within a few weeks of sowing, the antheridia are produced abundantly, containing antherozoids of extraordinary size, much larger than those of the mosses and ferns.

This paper contains the results of some observations upon the development of the male prothallium of *Equisetum arvense*, made in the botanical laboratory of the University of Michigan, in the spring of the present year.

Mature fertile plants were gathered on the 28th of April, and the following day the spores (Pl. 1, Fig. 1) were sown under glass, some in water and the remainder in damp earth. The second day after, while some were already divided into two cells, (Fig. 3), others had just begun to throw out the root hair (Fig. 2). Usually the first sign of active germination was the protrusion of a nearly colorless tube, the root hair (Fig. 2), followed very soon by a division of the body of the spore into two cells by a longitudinal septum (Fig. 3 *a*). Sometimes the second cell seems to be formed by a kind of budding (Fig. 3 *b*), but this, though not uncommon, is not the ordinary method. The root-hair grows with extreme rapidity, especially where the spores were growing in water (Fig. 4), and is destitute of chlorophyll, while in the body of the spore the chlorophyll is abundant. Almost immediately on the germination of the spore a very perceptible change occurs in the chlorophyll. While in the spore before germination the chlorophyll is evenly distributed throughout, as soon as germination begins there is a tendency in it to collect in distinct masses or chlorophyll bodies, which at an early stage in the development of the prothallium become very sharply marked. It is a difficult matter to give any definite rule for the method of cell division, as it differs so much in different individuals. Sometimes, though rarely, no root-hair is given off, the spore developing otherwise in a normal manner; again, in other cases there is a great enlargement of the spore without the formation of septa for a long time after germination commences (Fig. 8), (this was specially noticeable in the spores grown in water)—forming elongated flask-shaped cells.

On May 3d the spores presented the appearance shown in Figs. 4–6. Some were divided into four cells by longitudinal septa dividing the cells already formed, and in others (Fig. 5), the lower cell remained undivided, while the upper was divided into two, the cells having considerably grown in the meantime. No further change of importance was noted for several days, except a constant increase in the size of the cells. Figs. 7 *a b c* shows forms observed May 5th, the first showing a spore that seemed

to have divided into three cells at first, instead of two, as was ordinarily the case.

Many of the prothallia show a tendency to branch quite early, as is shown in Figs. 9 and 10, drawn May 8th. In these the basal cell remains undivided, and increases but little in length, while the others become elongated and divided by a longitudinal septum, forming two parallel rows of cells that finally develop into the two main branches of the older prothallium. This tendency is more plainly seen in Figs. 11 and 12, drawn at the same time from specimens that had developed further. In both of these the rows of cells have separated at the ends so as to plainly show the beginnings of the branches.

Sometimes, as in Fig. 14, there is considerable growth before any tendency to branching is shown; in this case the branch seeming to be formed by budding rather than by a division of the terminal cell. In contrast to this elongated form, there were numbers having the short thick form seen in Fig. 13.

Observations, made May 10th, showed that many of the larger prothallia had sent out a second root-hair from one of the lower cells. In some of the prothallia the branches also seemed inclined to divide again, thus forming four nearly equal branches instead of the two ordinarily present. This was more especially noticed in the case of spores growing in water, probably on account of the more nearly equal pressure on all sides, those growing on earth being flatter and having usually but two main branches. At this stage the chlorophyll bodies are remarkably distinct, being large and bright colored.

For some time after these observations were made, probably largely due to the unusually cold and dark weather, growth proceeded quite slowly, no noticeable change being remarked for almost a week; by the end of this time some of the more forward prothallia had assumed a distinctly two-branched form (Fig. 15), the branches being long and slender; from this point growth proceeded more rapidly, both laterally and longitudinally, the branches becoming flatter on account of the lateral growth of the cells and their division into new ones by longitudinal septa. The prothallia now begin to assume the irregular form that they have when mature, by giving off side branches at irregular intervals in which, as in the rapidly growing main branches, the protoplasm is strongly condensed at the ends (Fig. 16).

From this time on, the growth is very capricious; branches are given off, apparently without any definite order, the cells already formed also dividing, so as to make the prothallium broader and thicker. This growth continues until antheridia are to be formed.

For two or three weeks the spores grown in water and in moist earth, develop in much the same manner, but finally those in water grow much less rapidly, though seeming to retain their vitality to some extent. Their growth is more erratic, many growing for a long time without dividing, forming single cells that are very much elongated; others develop without sending out any root-hair, and nearly all, after three or four weeks, stop growing, or grow very feebly. When sown in water the spores soon sink and form a filmy green mass closely resembling a small alga. Those grown on earth form bright green, velvety masses that might readily be taken for a small moss. In both cases the long root-hairs, becoming entangled, make the prothallia cling together in great numbers where the spores are thickly sown. The abnormal development in water is probably owing to the lack of proper nutriment as well as to the different physical conditions to which the spores are subjected.

For a considerable time before antheridia were formed, the prothallia increased but little in length, but became noticeably broader and thicker, the ends of the main branches growing blunter and dividing up into short branches, so as to become somewhat club-shaped (Fig. 17). This process was slow at first, but after the first antherozoids were formed, there was a rapid increase in the size of the prothallium.

The first mature antherozoids were observed June 7th, nearly six weeks from the time the spores were sown; Fig. 20 gives the appearance presented by the prothallium at the time that the first antheridia are formed. Hofmeister gives five weeks as the time requisite for the production of the first antherozoids, but this difference of a few days in the time, may be readily accounted for by the extraordinary lateness of the past spring.

From the very great simplicity of the structure of the antheridium, it is very difficult to say just when it begins to be formed, for it is merely an excavation or cavity in the end of a branch of the prothallium that becomes filled with protoplasm more dense than that in the body of the prothallium. After the mature an-

theridia were formed, it was an easy matter to trace the development back, but it was impossible to determine just where it began. The process was as follows: After the branch in which the antheridium was to be formed had attained sufficient size, there was a concentration of protoplasm at this point (Fig. 18), a cavity being gradually formed, at first indistinct, but finally assuming a nearly regular oval shape (Fig. 19). This mass of protoplasm soon breaks up into small round bodies that are discharged as antherozoids. The first antheridia are formed singly, but later (Fig. 19) two or three are formed almost simultaneously at the end of a single branch. When the antherozoids are mature, the cells surrounding the interior cavity of the antheridium separate, leaving an opening by which they escape. Usually the whole mass of antherozoids is discharged in a few minutes, but sometimes the discharge is more gradual. Each antherozoid is enclosed in, and lies coiled up within, a membrane. After resting for a few moments this sac bursts, freeing the enclosed antherozoid, which immediately swims rapidly away with a peculiar undulatory movement due to its spiral form. The most noticeable thing about them is their great size, for while most antherozoids are so minute as to look like mere specks, even when a high power is employed, these are readily studied with an ordinary ⅔ objective. They are quickly killed by the application of iodine by means of which the cilia are made rigid, standing out in all directions from the thicker end of the antherozoid, and plainly visible with the low power. The body is long and slender, tapering to a point at one end and bearing the remains of the enveloping sac in the inner side. The body is contracted, becoming shorter and blunter after iodine is applied.

In germinating the spores, the only precaution necessary is to keep the atmosphere around them moderately damp. In making the foregoing observations, this was done by sowing the spores on damp earth in unglazed earthen saucers which were placed under bell jars. By giving water every two or three days no difficulty was experienced in keeping the prothallia in a healthy condition.

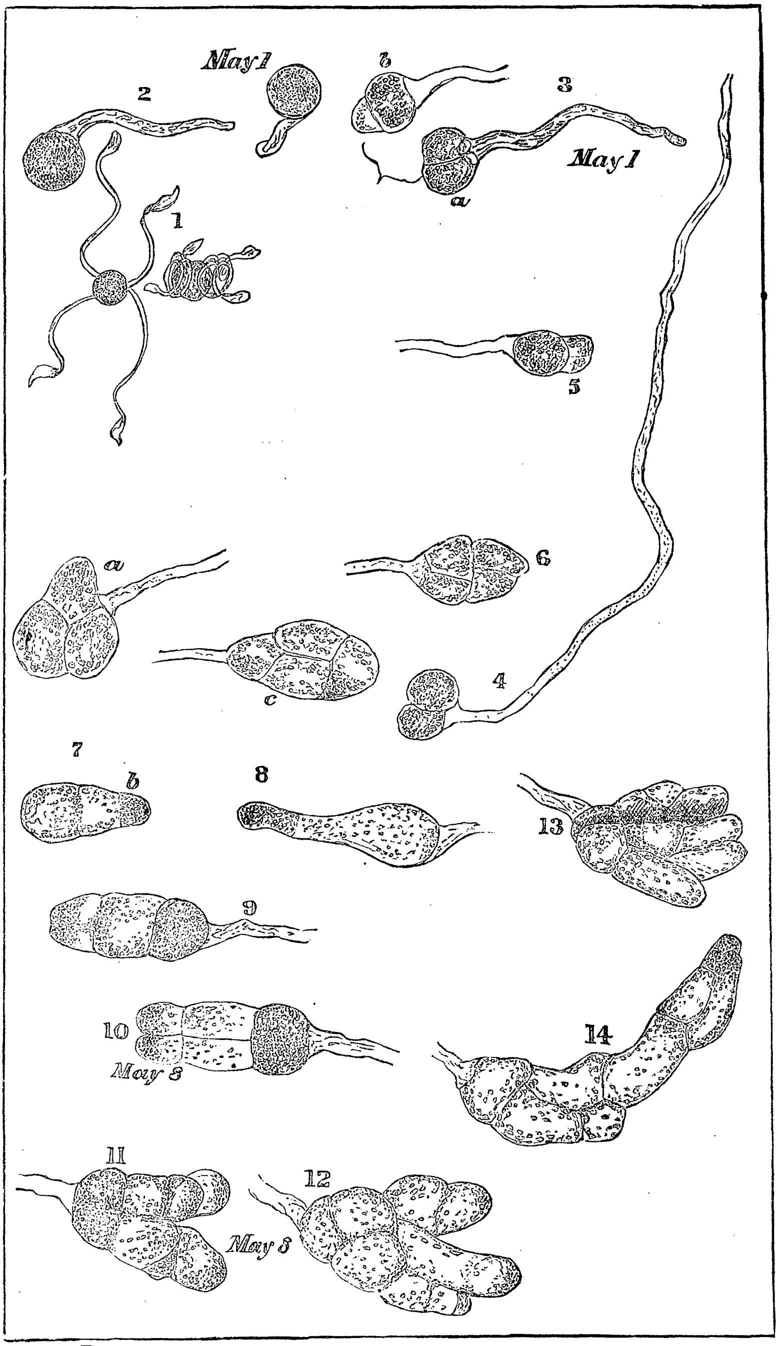
EXPLANATION OF PLATE I.

FIG. 1.—Two spores, one with the elaters coiled around it, the other with the elaters expanded.

FIGS. 2 and 3.—Germinating spores on May 1st.

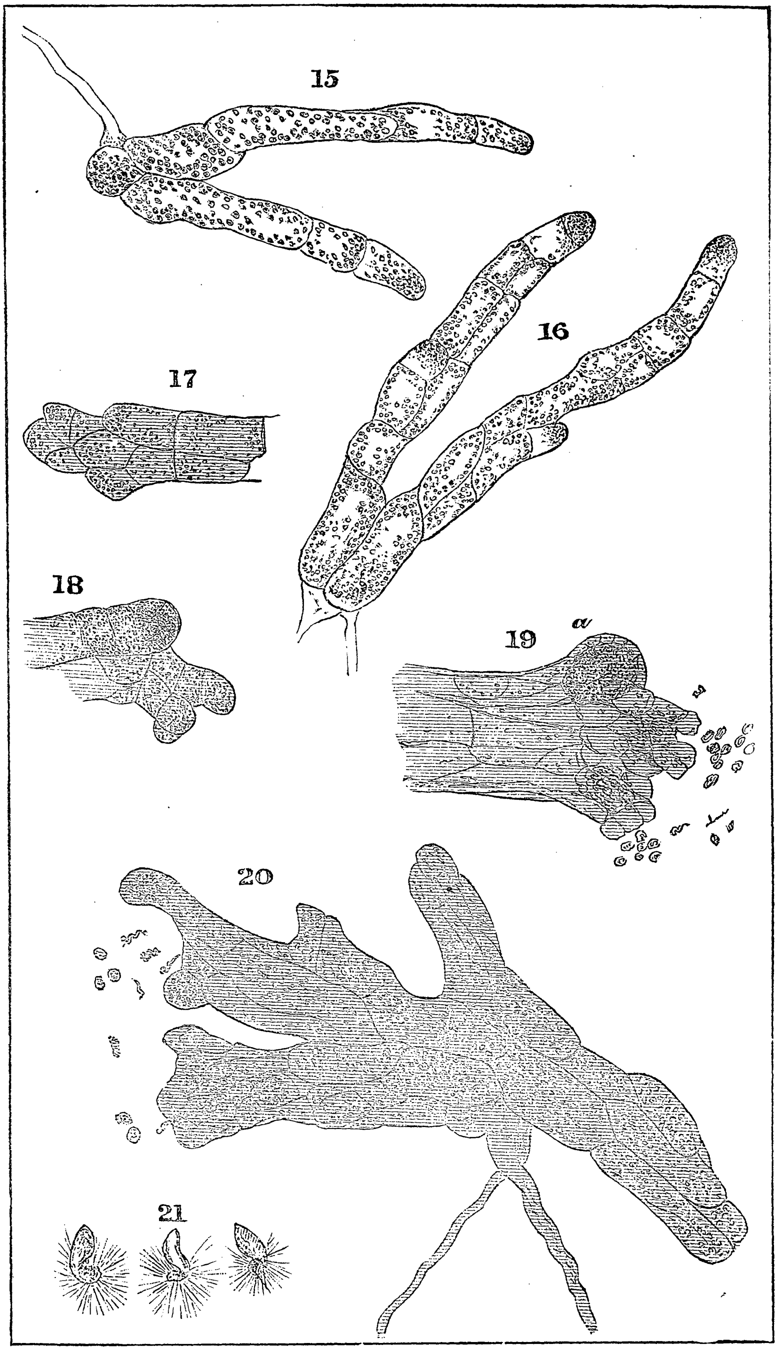
" 4, 5 and 6.—Germinating spores on May 3d, showing variations in mode of division.

PLATE I.



DEVELOPMENT OF THE MALE PROTHALLIUM OF THE HORSETAIL.

PLATE II.



DEVELOPMENT OF THE MALE PROTHALLIUM OF THE HORSETAIL.

FIGS. 7 and 8.—Germinating spores on May 5th, showing variations in mode of division.

" 9 and 10.—Young prothallia on May 8th.

" 11 and 12.—Young prothallia on May 8th, showing early branching.

FIG. 13.—Short, thick prothallium (May 8th).

" 14.—Young prothallium, much elongated (May 8th).

All the figures magnified 125 diameters.

EXPLANATION OF PLATE II.

FIG. 15.—Branching prothallium, May 18th.

" 16.—Branching prothallium, showing protoplasm condensed in the ends of the cells, May 24th.

" 17.—End of branch of older prothallium.

" 18.—Young antheridium.

" 19.—Antheridia; *a*, unopened; *b*, opened, with escaping antherozoid cells, June 13th.

" 20.—Prothallium with antheridia and antherozoids, June 10th.

" 21.—Antherozoids, mag. 350.

All the figures excepting Fig. 21 magnified 125 diameters.

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ON THE GEOLOGICAL EFFECTS OF A VARYING ROTATION OF THE EARTH.

BY PROFESSOR J. E. TODD.

THE fact of variation in the velocity of the earth's rotation, seems so nearly established as to call for a consideration of its effects on geology. One can scarcely read Professor Newcomb's masterly paper on the acceleration of the moon without feeling that the ability of astronomers to state the exact times of eclipses, especially of those in past time, has been greatly overrated. As he himself says in conclusion, "If Hansen is right, then Ptolemaic eclipses might be harmonized, but the Arabian would be ten to fifteen minutes out of the way, which to my mind seems very improbable. Apparently, therefore, we can hardly avoid accepting one of these propositions: Either the recently accepted value of the acceleration, and the usual interpretations of the ancient solar eclipses are to be radically altered, the eclipse of — 556 not having been total at Larissa, and that of — 584 not having been total in Asia Minor; or the mean motion of the moon is, in the course of centuries, subject to changes so wide that it is not possible to assign any definite value to the acceleration."[1]

We learn from this same paper reasons for believing that the

[1] Newcomb. Observations on the moon before 1750, p. 278. (Washington Ast. and Met. Observations, Vol. XXII, App. II.)